EMS Annual Meeting 2024

Barcelona, Catalonia & Online | 5–9 September 2024

EMS2024-279

A study of a damaging hailstorm episode in the Basque Country: The Vitoria-Gasteiz case of July 6, 2023

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1. Introduction

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- In the warm season (from May to September), storms generated by deep convection are frequent in the Basque Country, although not in all cases storms produced severe conditions.
- Impacts are usually caused by intense showers exceeding 30 mm in 1 hour or 10 mm in 10 minutes, especially if the showers affect urban areas, and by hail and wind gusts associated with the storms.
- Generally, surface pressure patterns are not very well defined in these situations and a barometric swamp or relative thermal lows appear.
- At high atmospheric levels/in the upper atmosphere, southwest wind usually predominates and there is often a trough configuration with its axe over the west of the Iberian Peninsula.
- In many cases, storms are created in the south or southwest outside the Basque Country, although they can also be generated within. This depends on the convergence areas in low levels and instability degree above the Basque Country.
- In our region, storms usually move from southwest to northeast. This is the most frequent movement on southwest flow in high levels. In some circumstances, such as in this case, deviation in the storms movement might be relevant in relation to the main flow.

2. General environment

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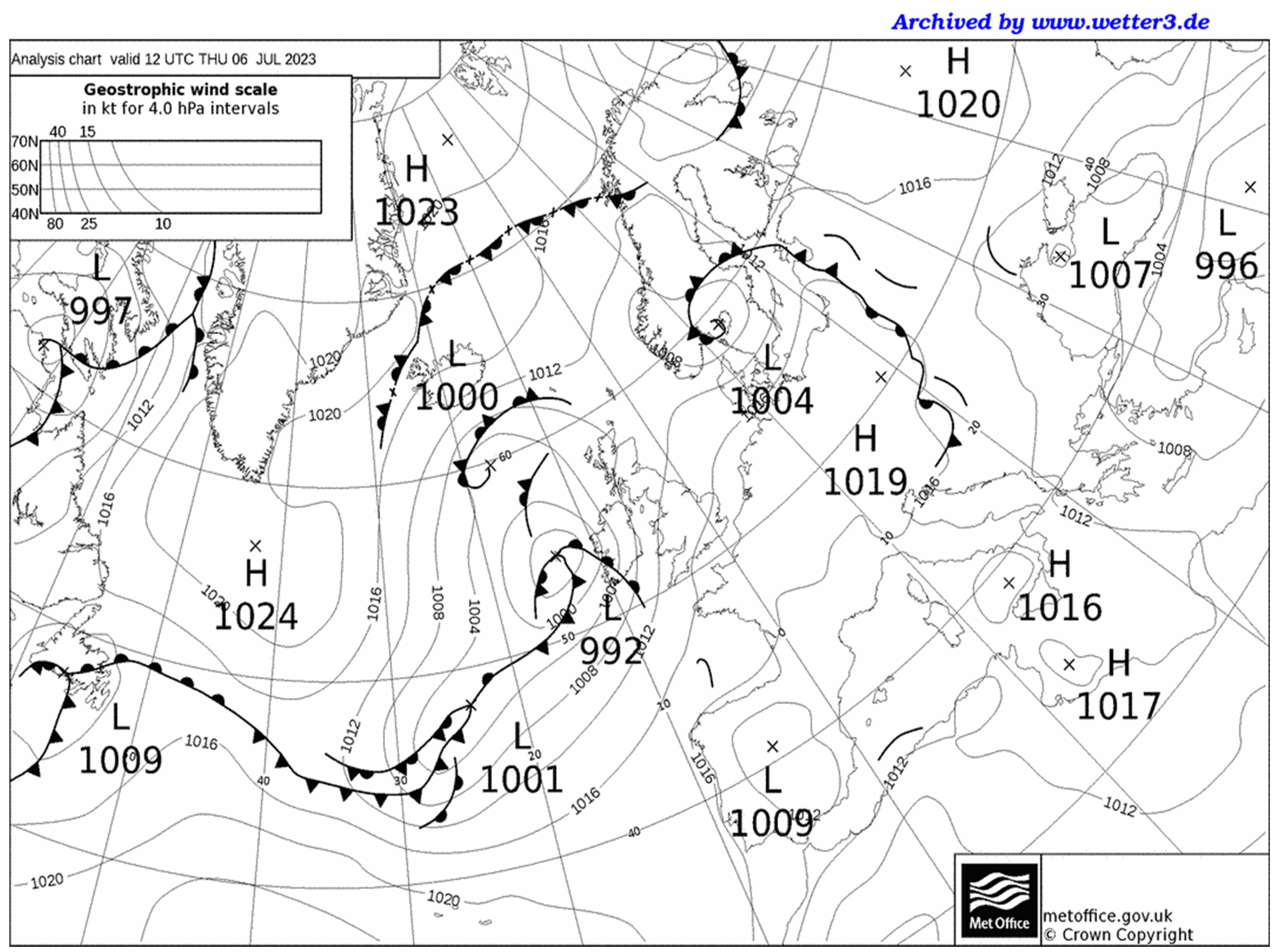
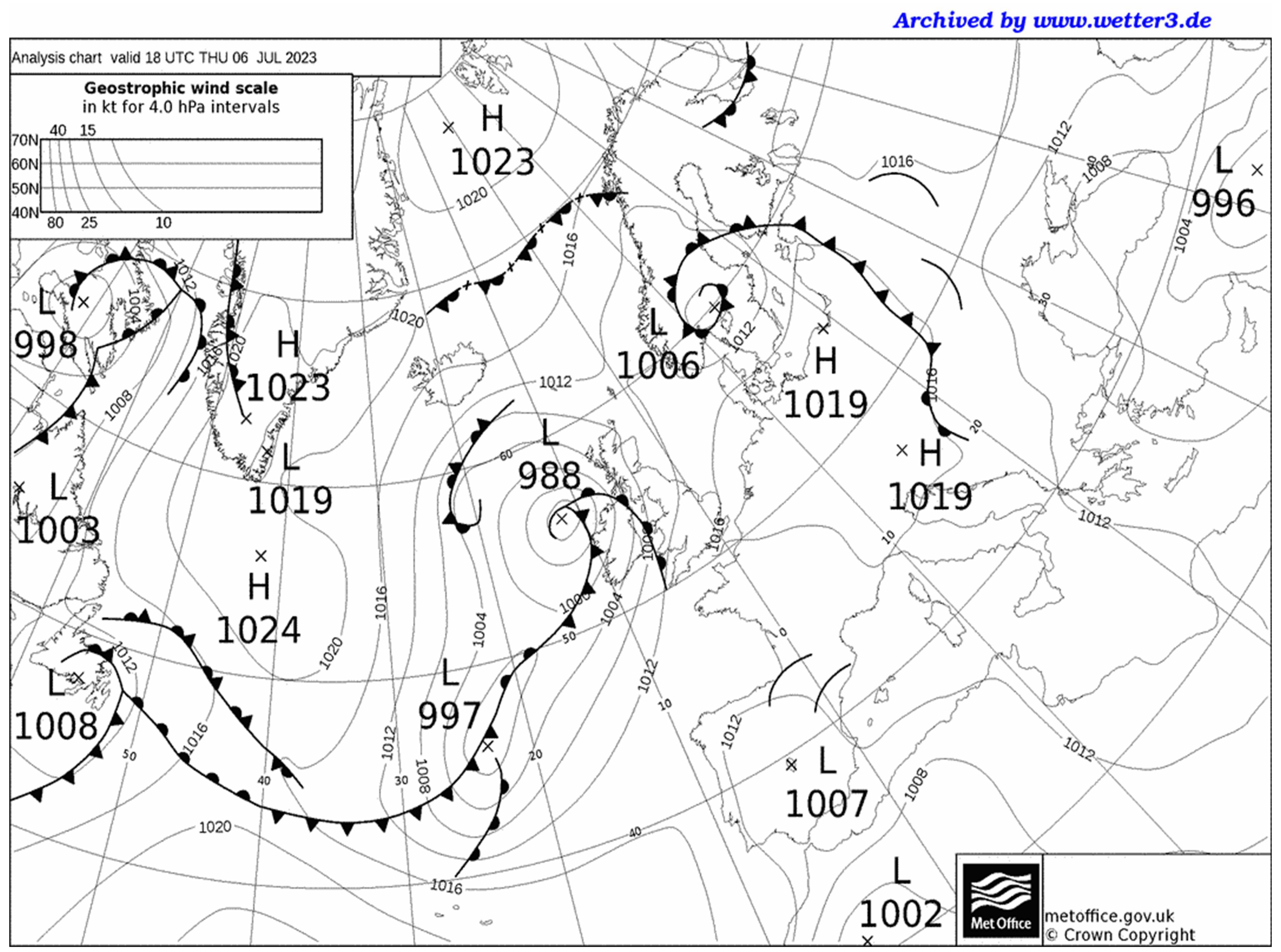
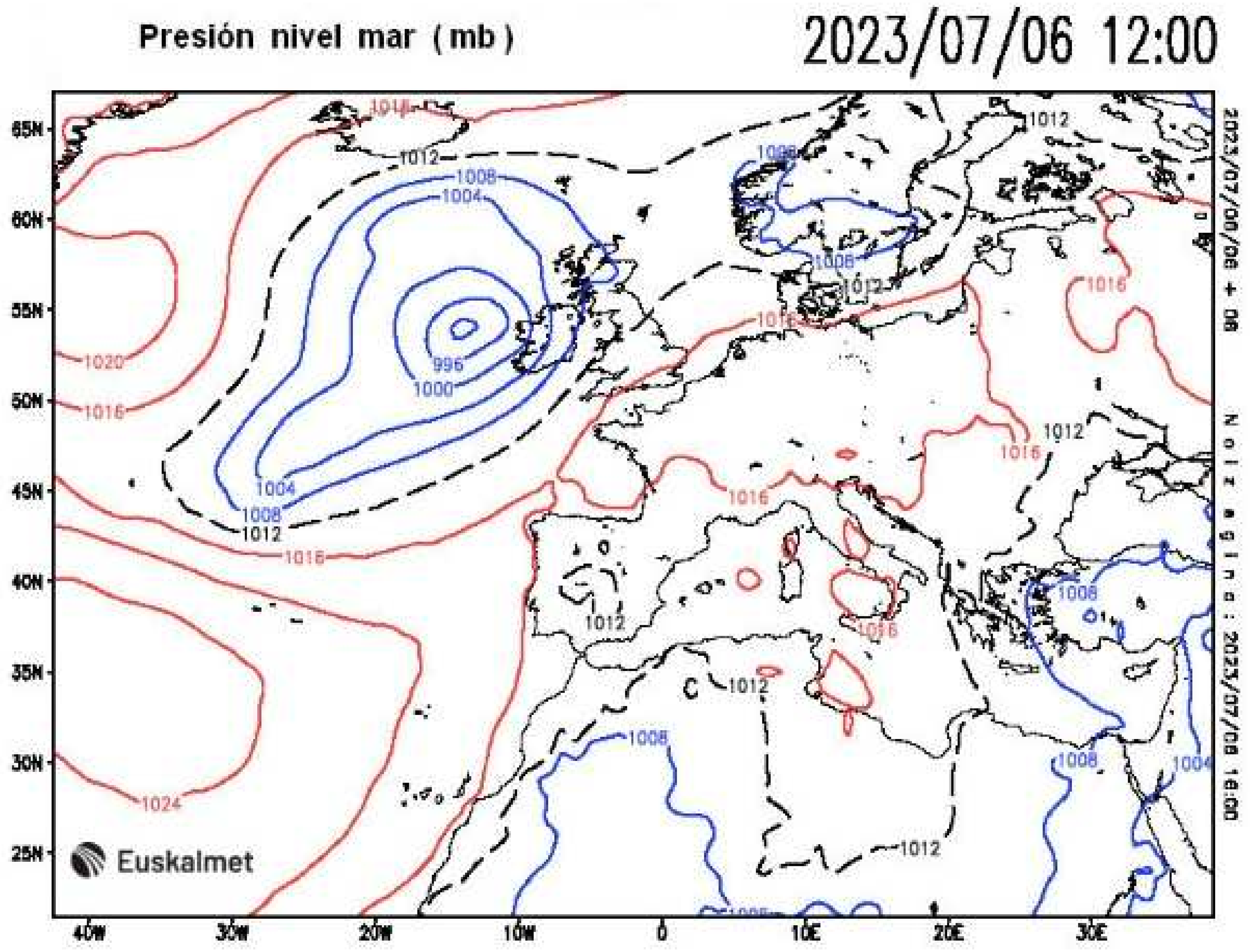
The surface weather situation over the Iberian Peninsula is undefined with a barometric swamp, and the typical summer thermal low is formed

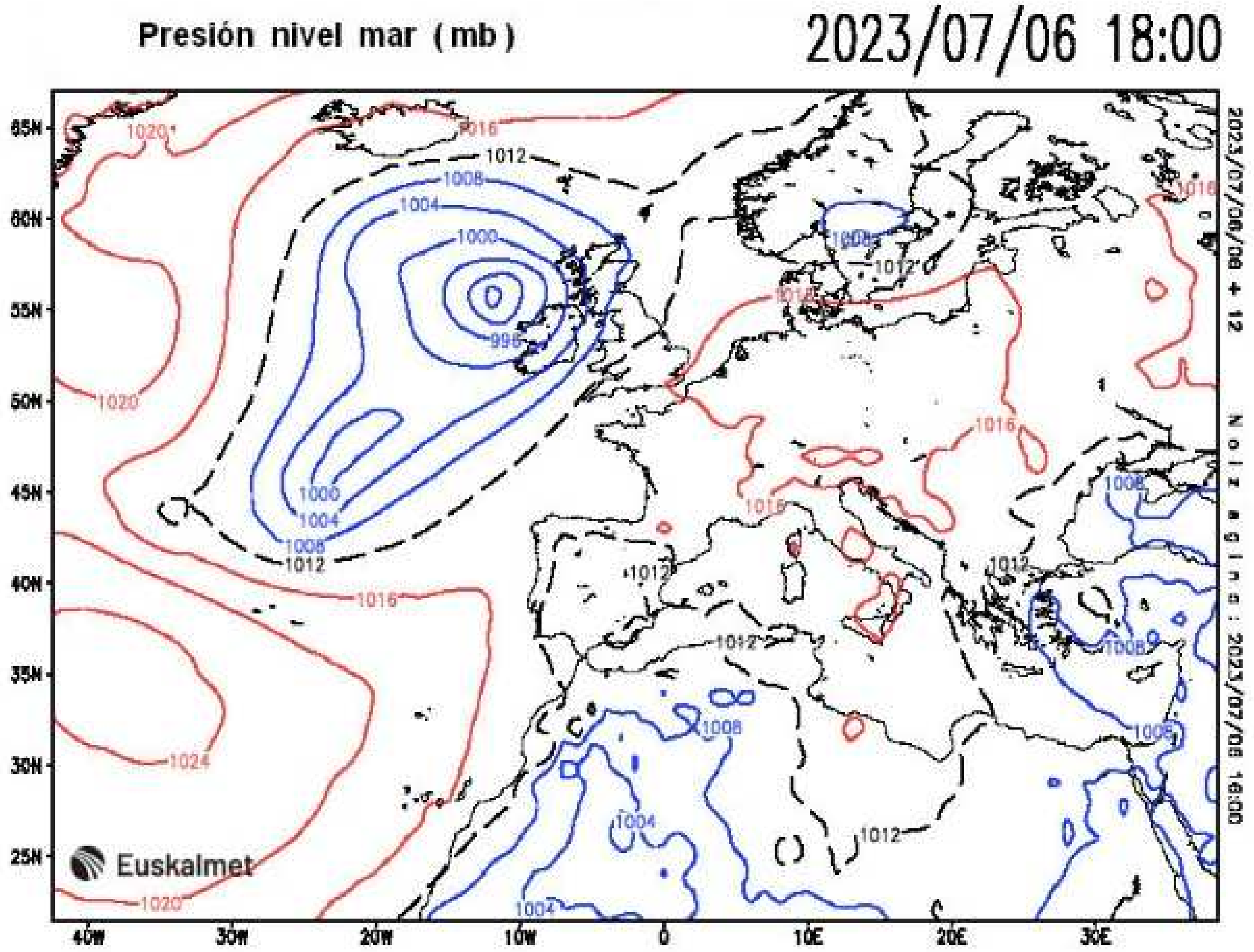
UKMO surface analysis





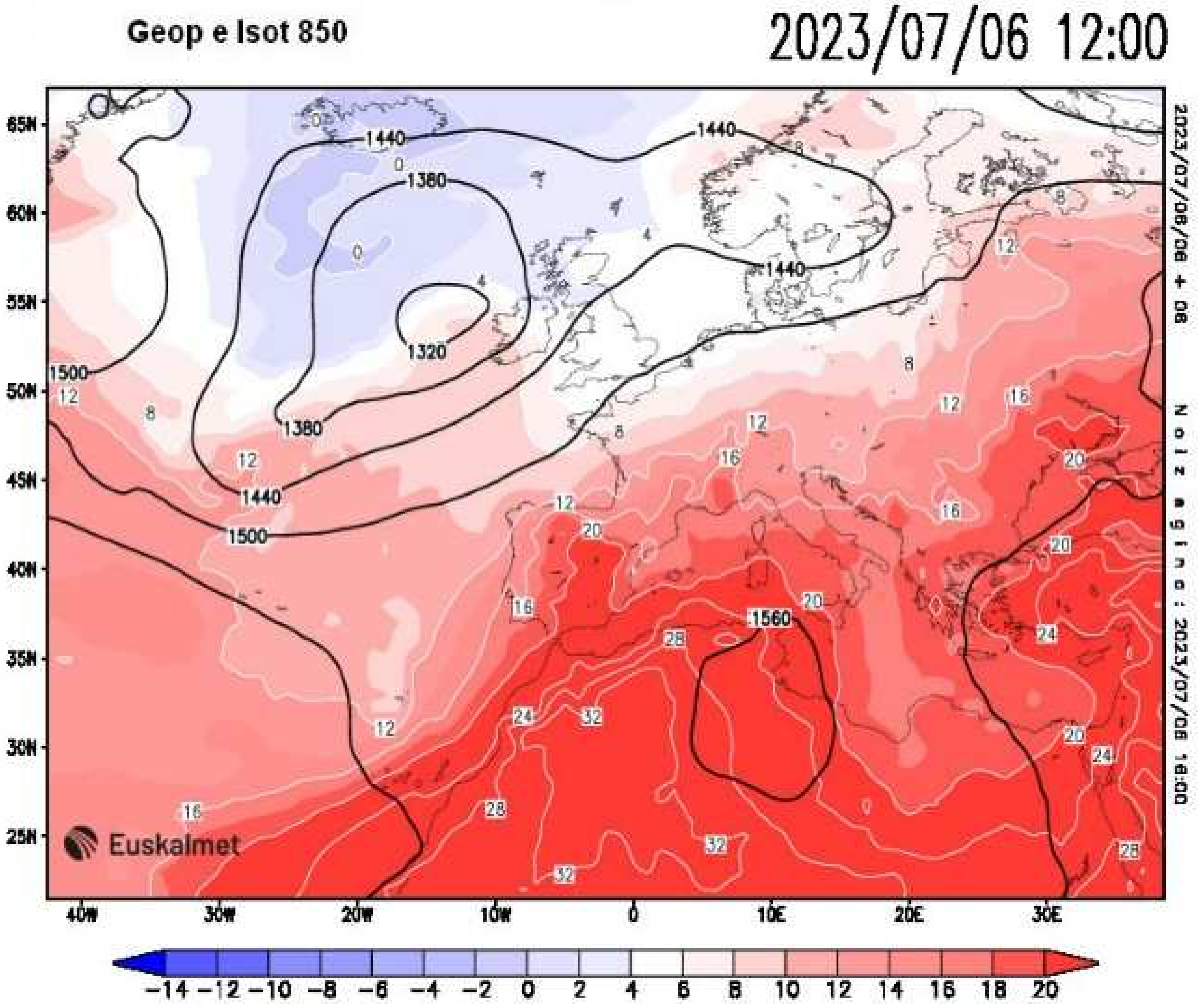
SLP (sea level pressure) at 12 and 18 UTC.

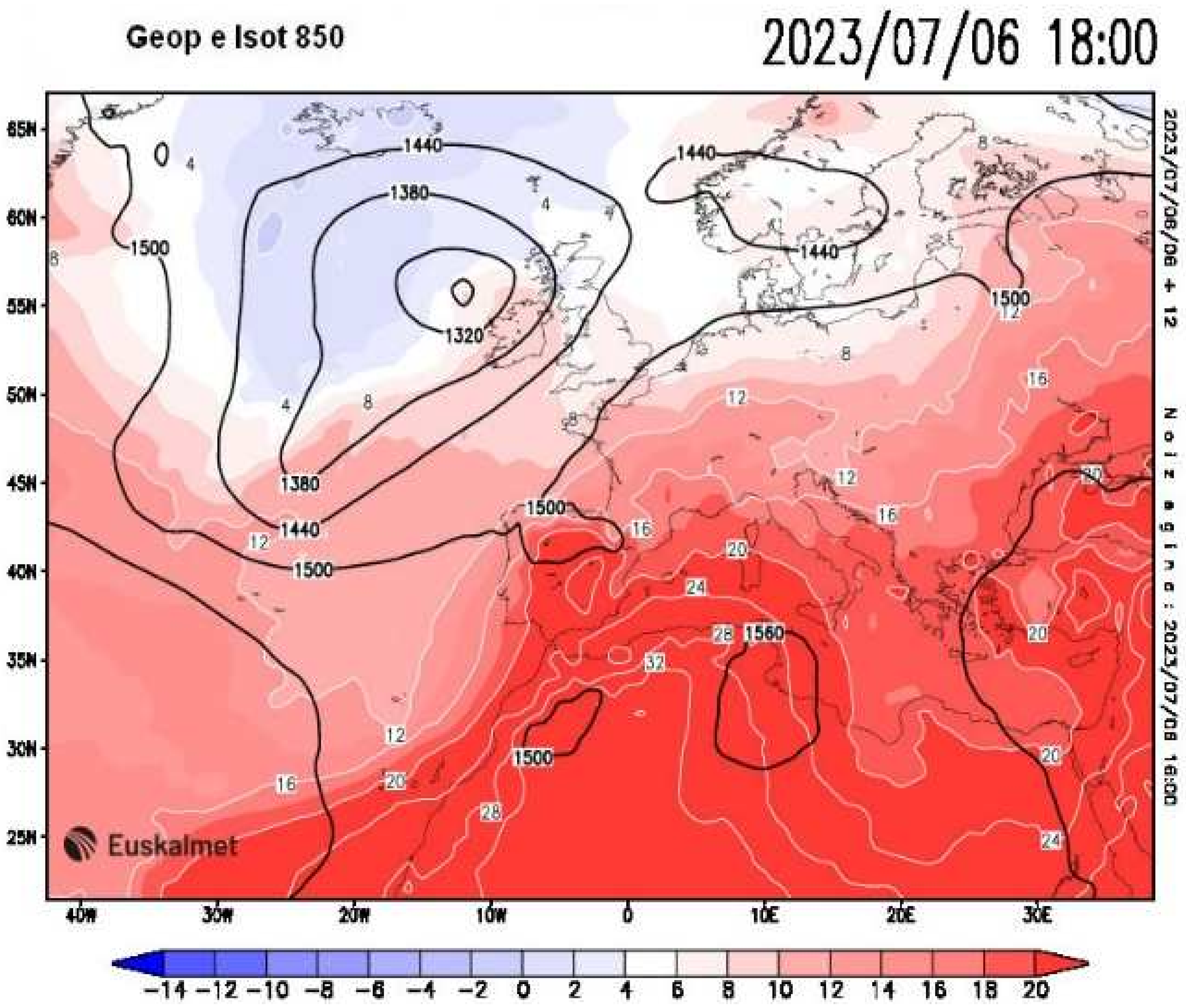




2. General environment

In the lower layers, there is an inflow of warm air from the south extending northwards

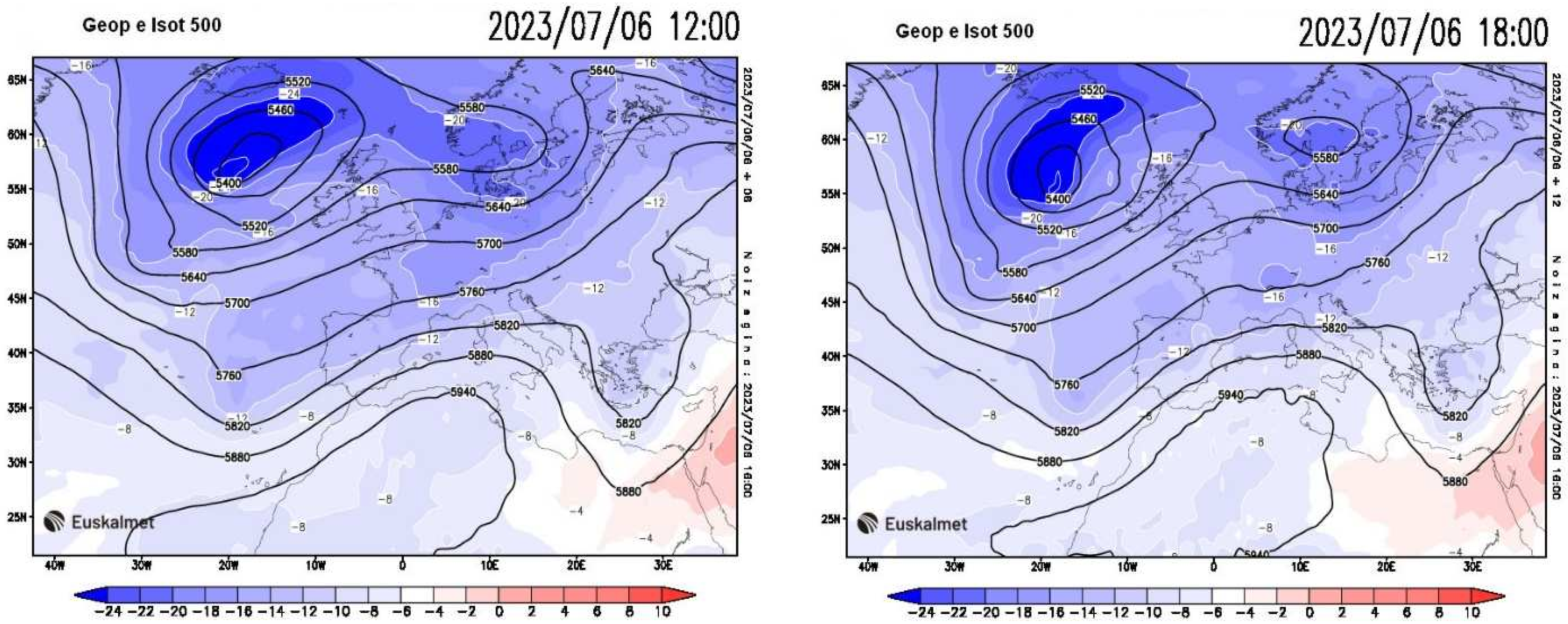




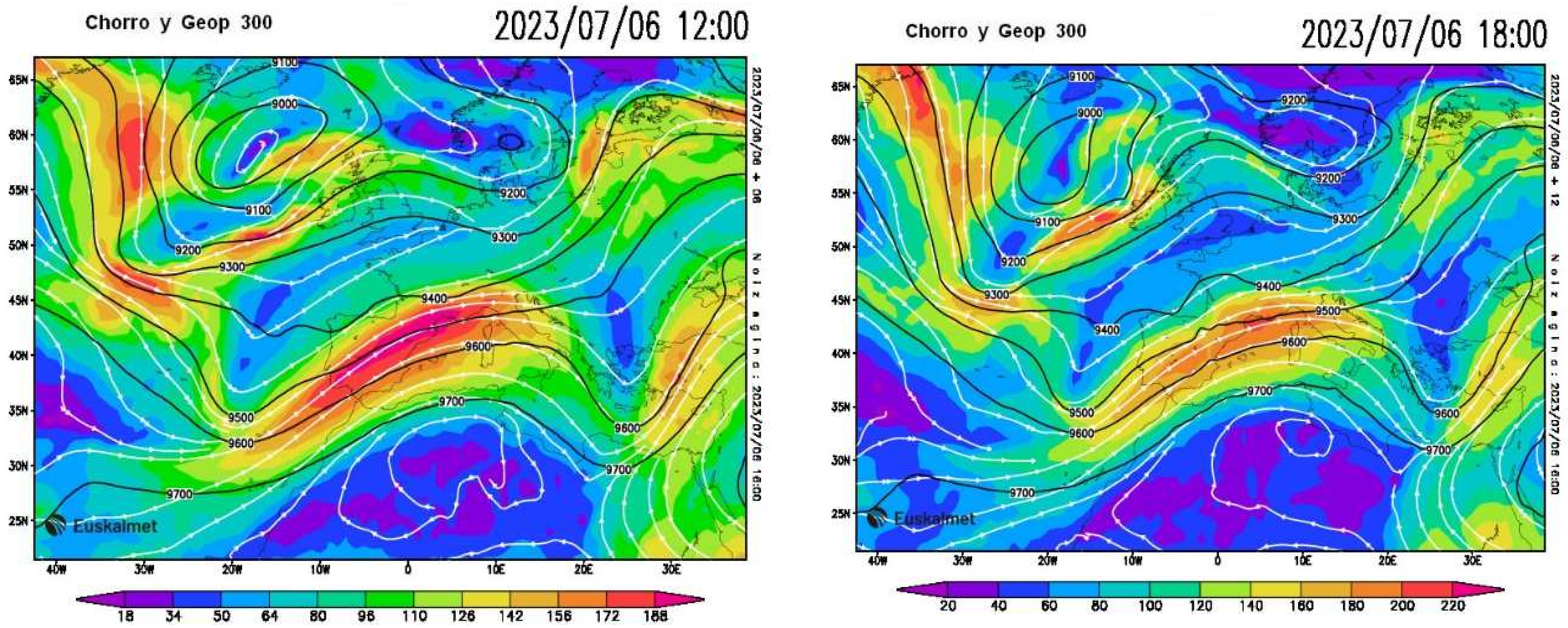
Geopotential and isotherms at 850 hPa level at 12 and 18 UTC.

2. General environment

In the middle and upper layers, the flow is markedly from the SW with a slight trough due to the passage of the subtropical jet stream, which presents an undulation. The upstream branch located over the Iberian Peninsula



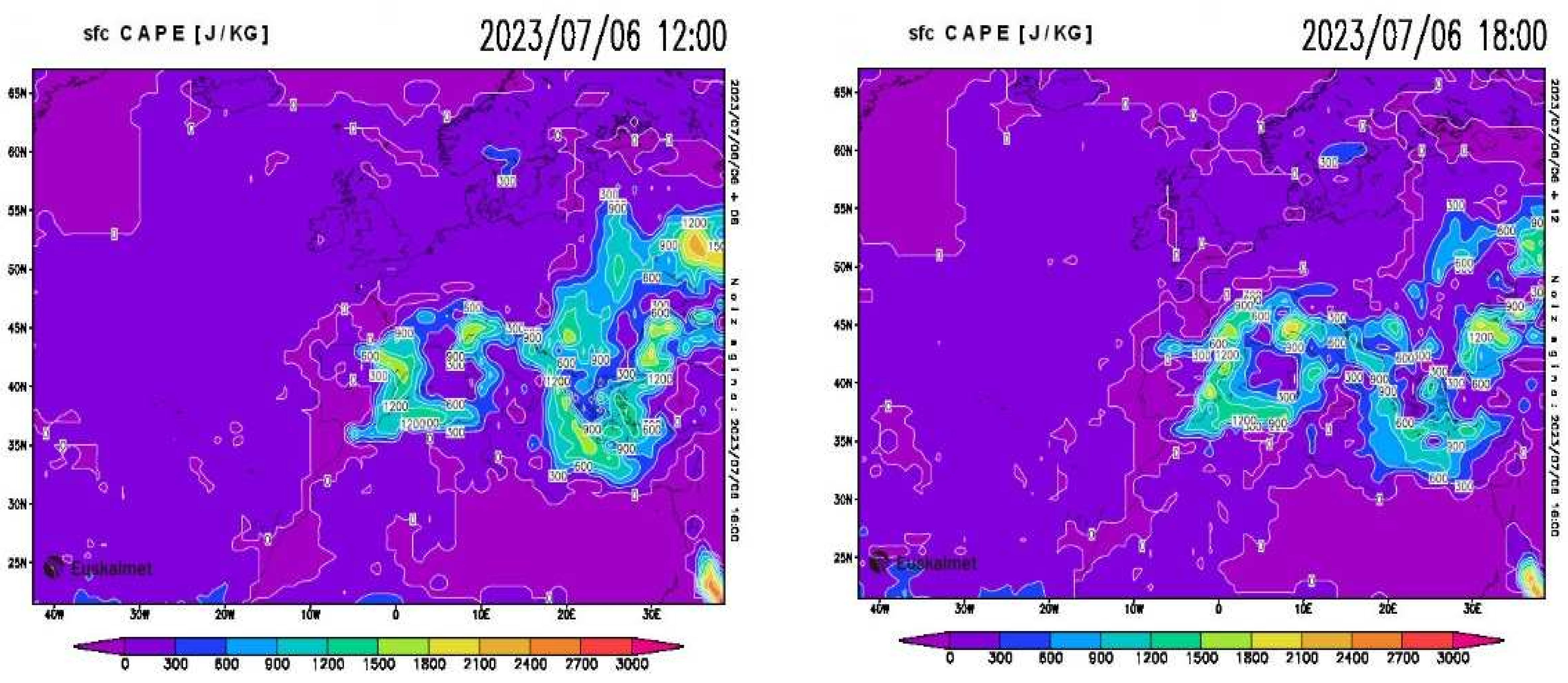
Geopotential and isotherms in 500 hPa level at 12 and 18 UTC.



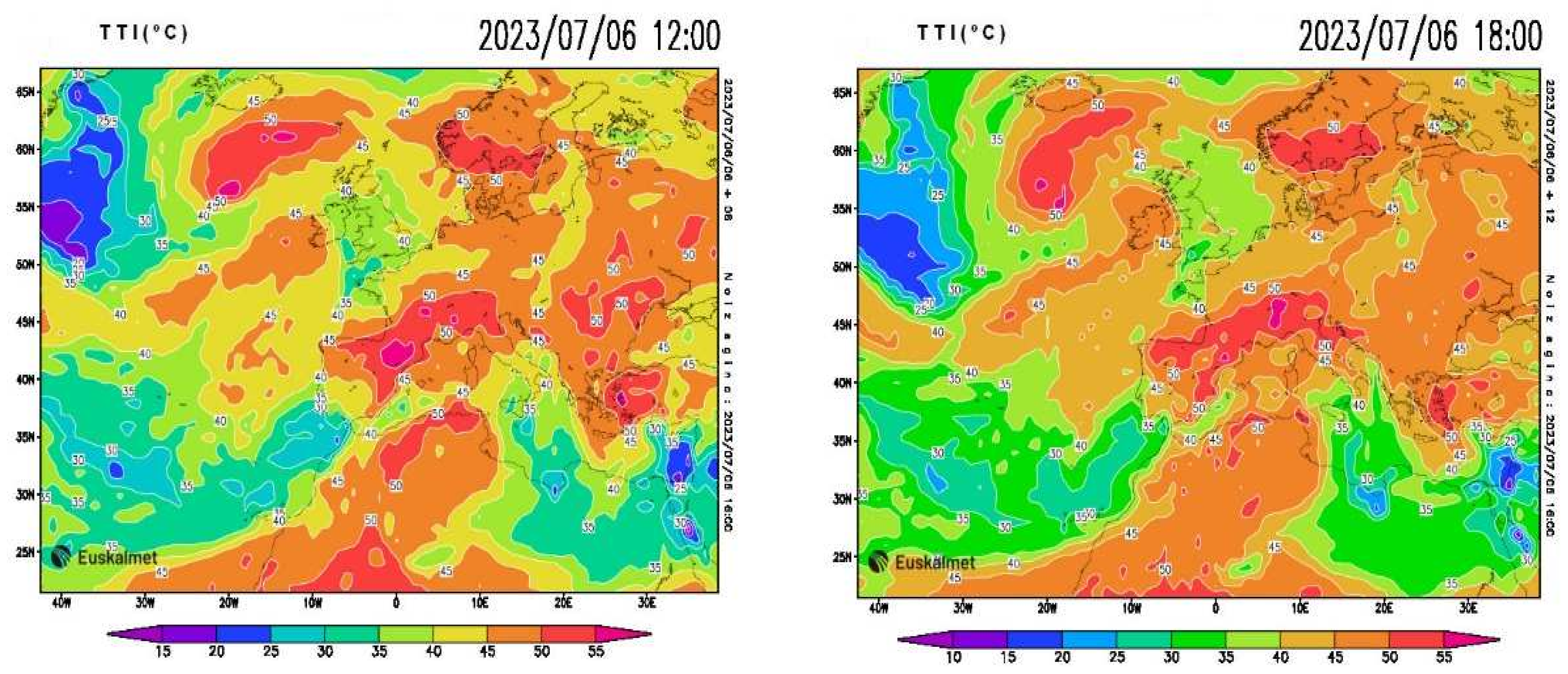
Geopotential and isotherms in 500 hPa level at 12 and 18 UTC.

2. General environment

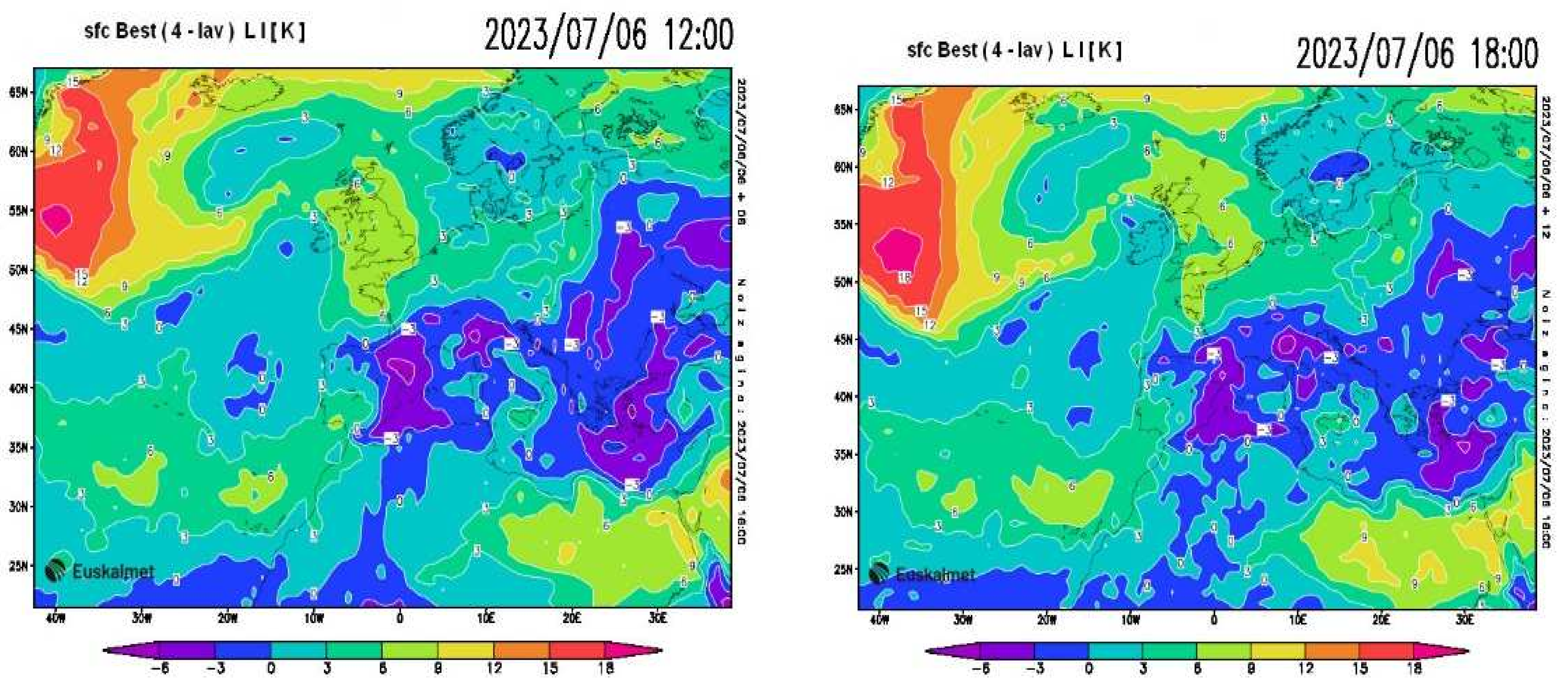
The instability indices show a high degree of instability, with LI (lifted index) values below -3 ºK, a CAPE higher than 600 J/kg, in general between 600 and 1500 J/kg, and the TTI between 50 and 55 ºC. Precipitable water shows values around 25-30 kg/m2.



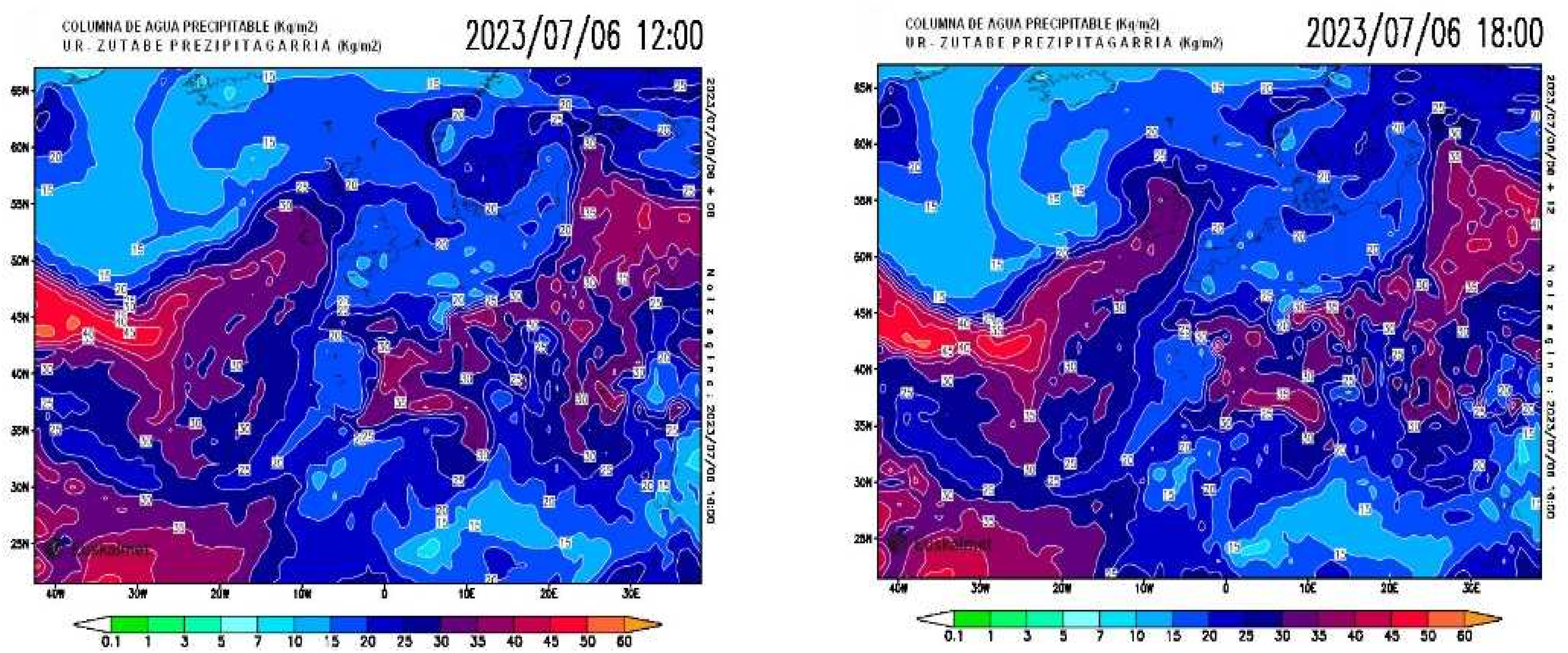
CAPE at 12 and 18 UTC.



TTI at 12 and 18 UTC.



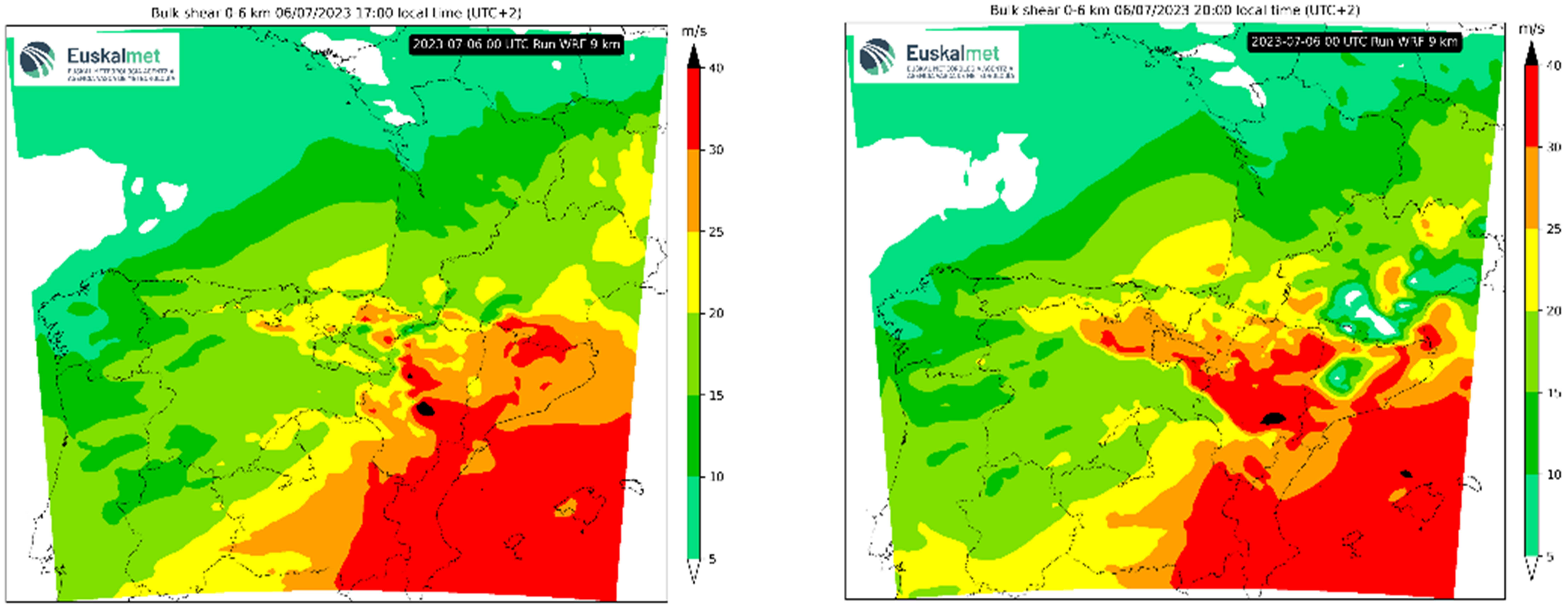
LI at 12 and 18 UTC.



Precipitable water at 12 and 18 UTC.

2. General environment

Due to the passage of the subtropical jet, the SW wind at upper layers intensifies and causes the 0-6 km shear (deep-layer shear) to reach high values around 20 m/s, locally above 30 m/s.

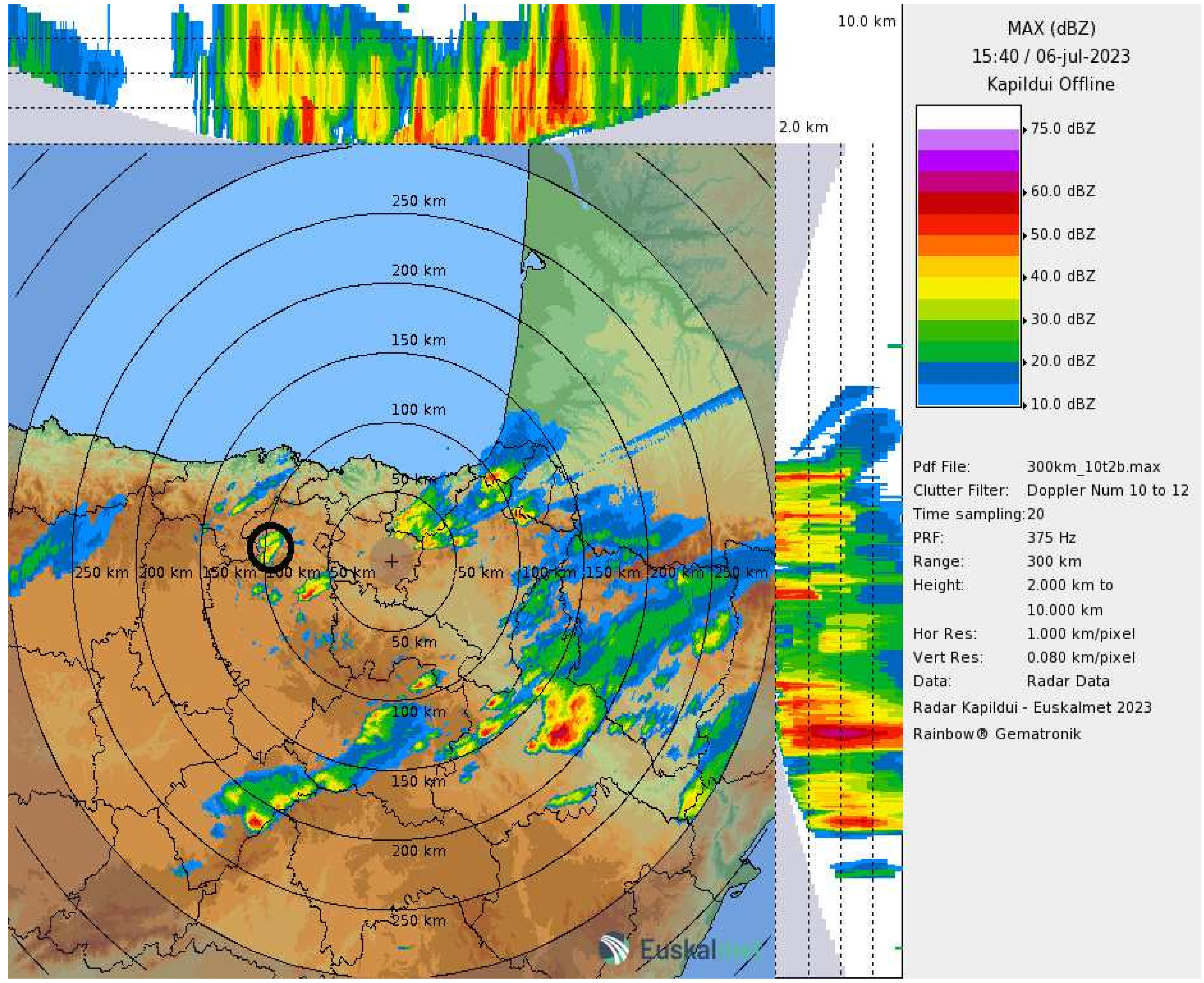


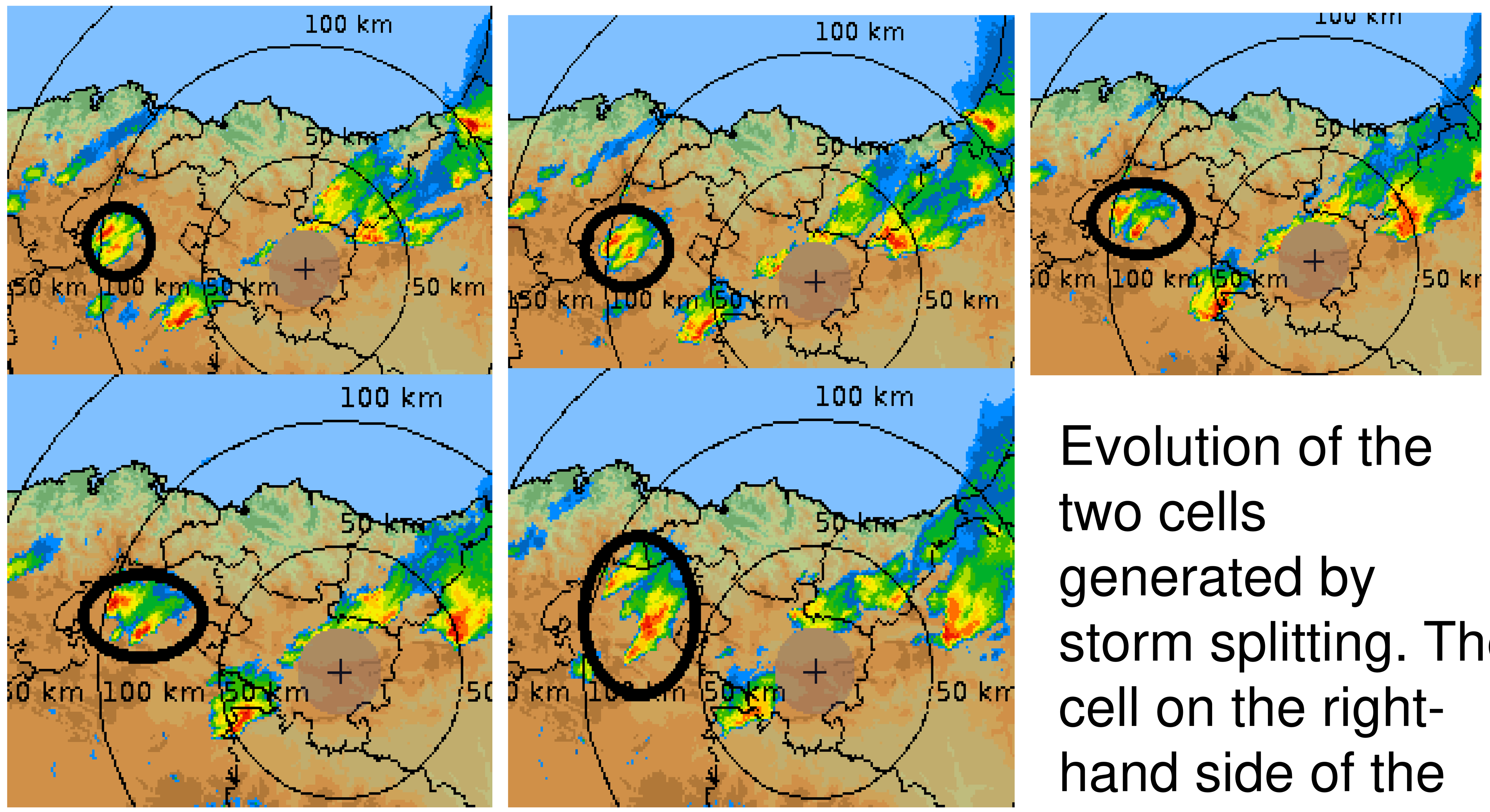
Deep layer shear at 15 and 18 UTC.

Therefore there ere favourable conditions for the formation of organised storms and the generation of supercell structures.

3. Storm environment and observations

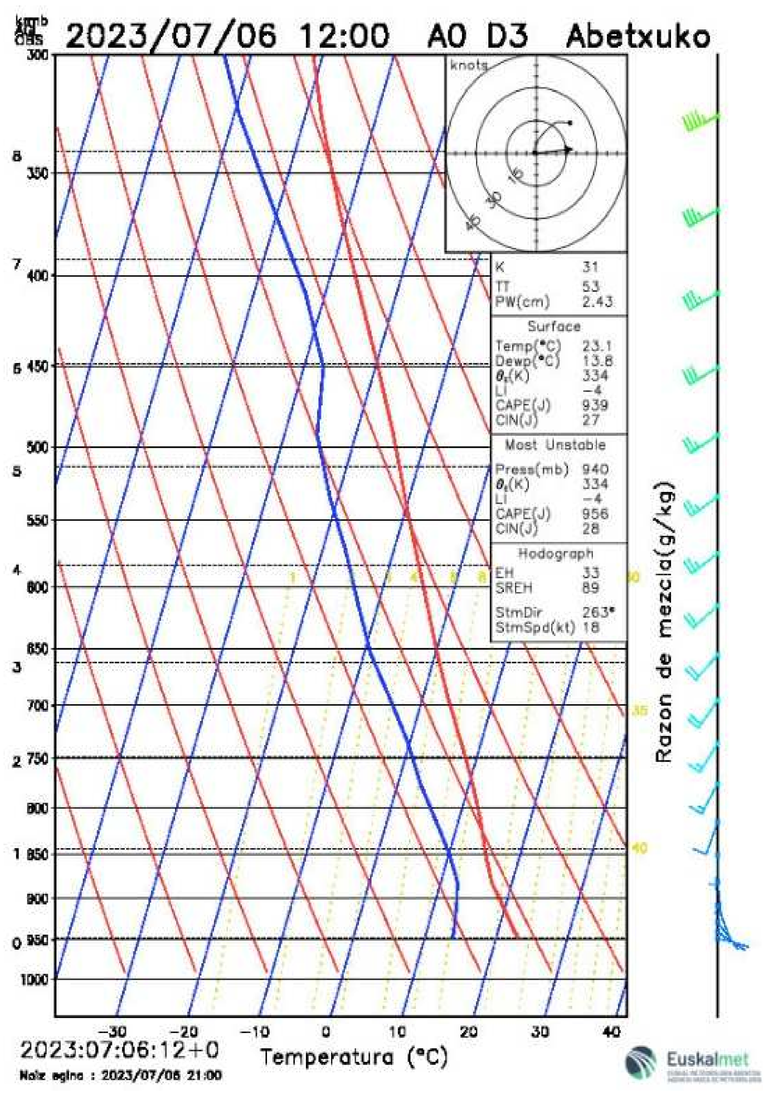
- Within this unstable synoptic environment, very active convective cells are generated during the afternoon, moving from southwest to northeast, although the cell affecting Vitoria-Gasteiz has a marked west-east movement.
- The storm that affects Vitoria-Gasteiz forms in the area of Burgos around 17:30 hours, and a storm-splitting occurs, dividing into two cells in which the cell at the right-hand side of the movement is strengthened in coherence with the structure of the wind at height and the predicted hodograph that presents a clockwise rotation. The cell moves to the right of the shear vector.





Evolution of the two cells generated by storm splitting. The cell on the right-hand side of the movement is clearly intensified.

Predicted sounding with the hodograph for Abetxuko (Vitoria-Gasteiz) at 12 UTC (WRF model).



3. Storm environment and observations

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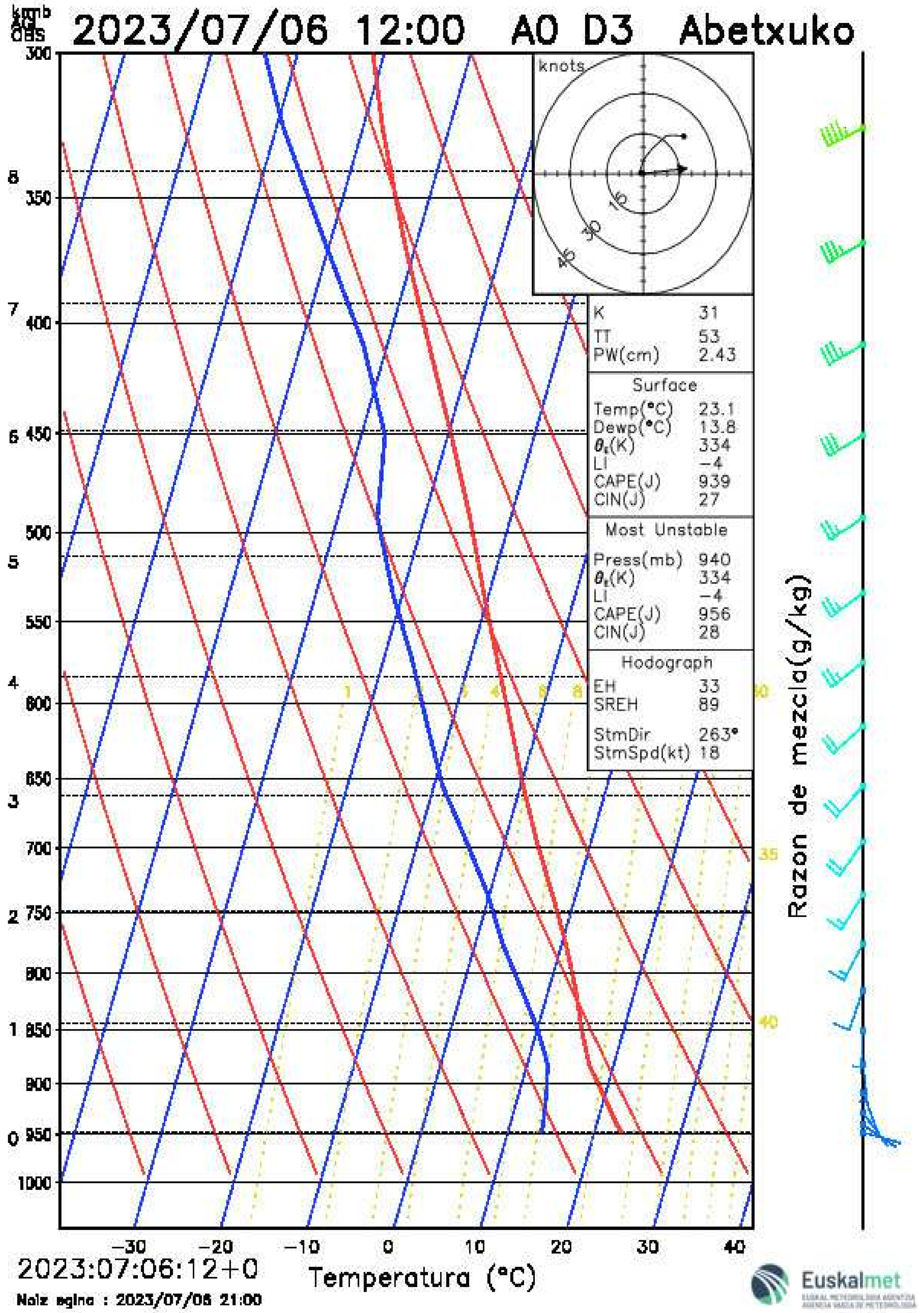
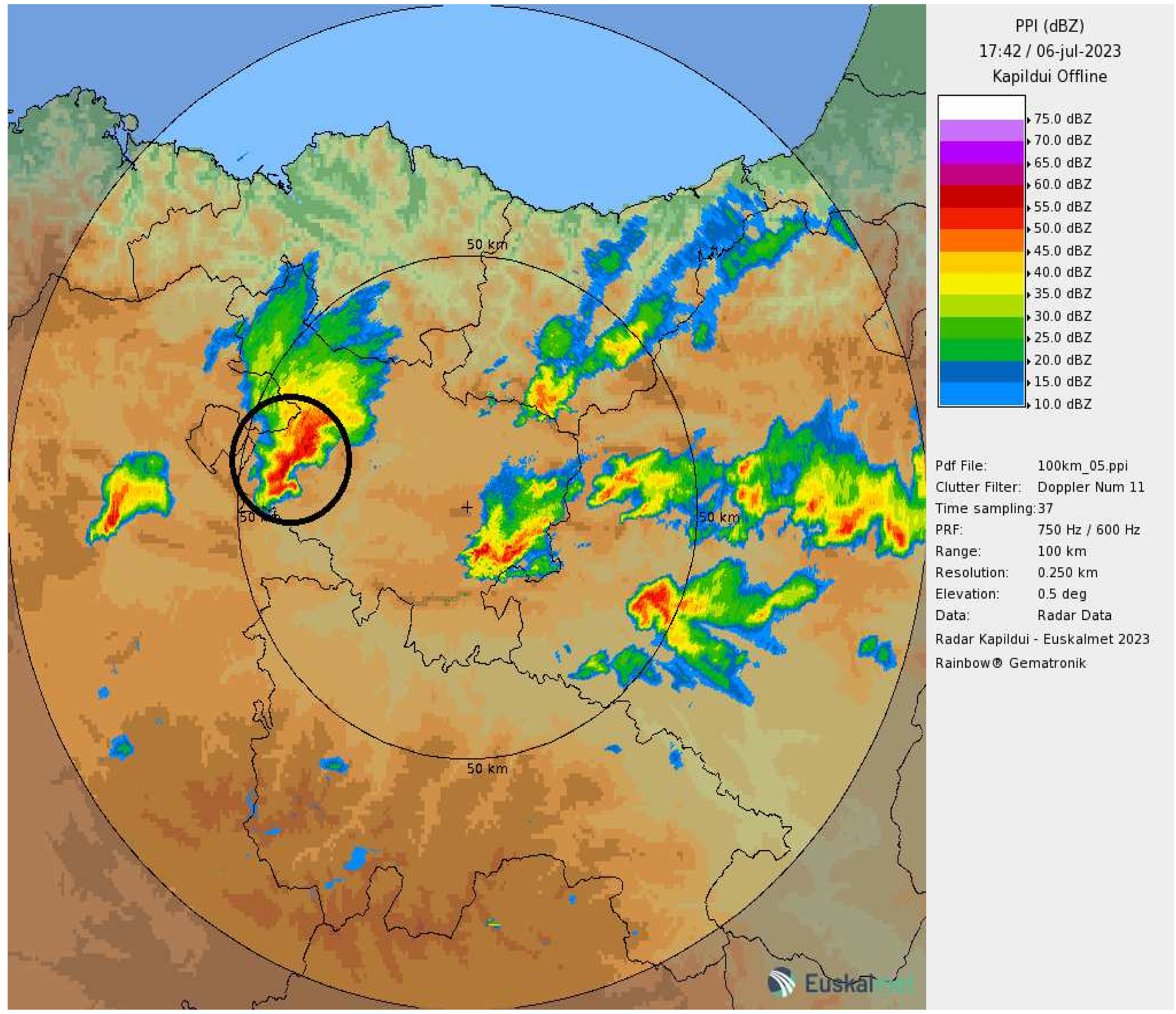
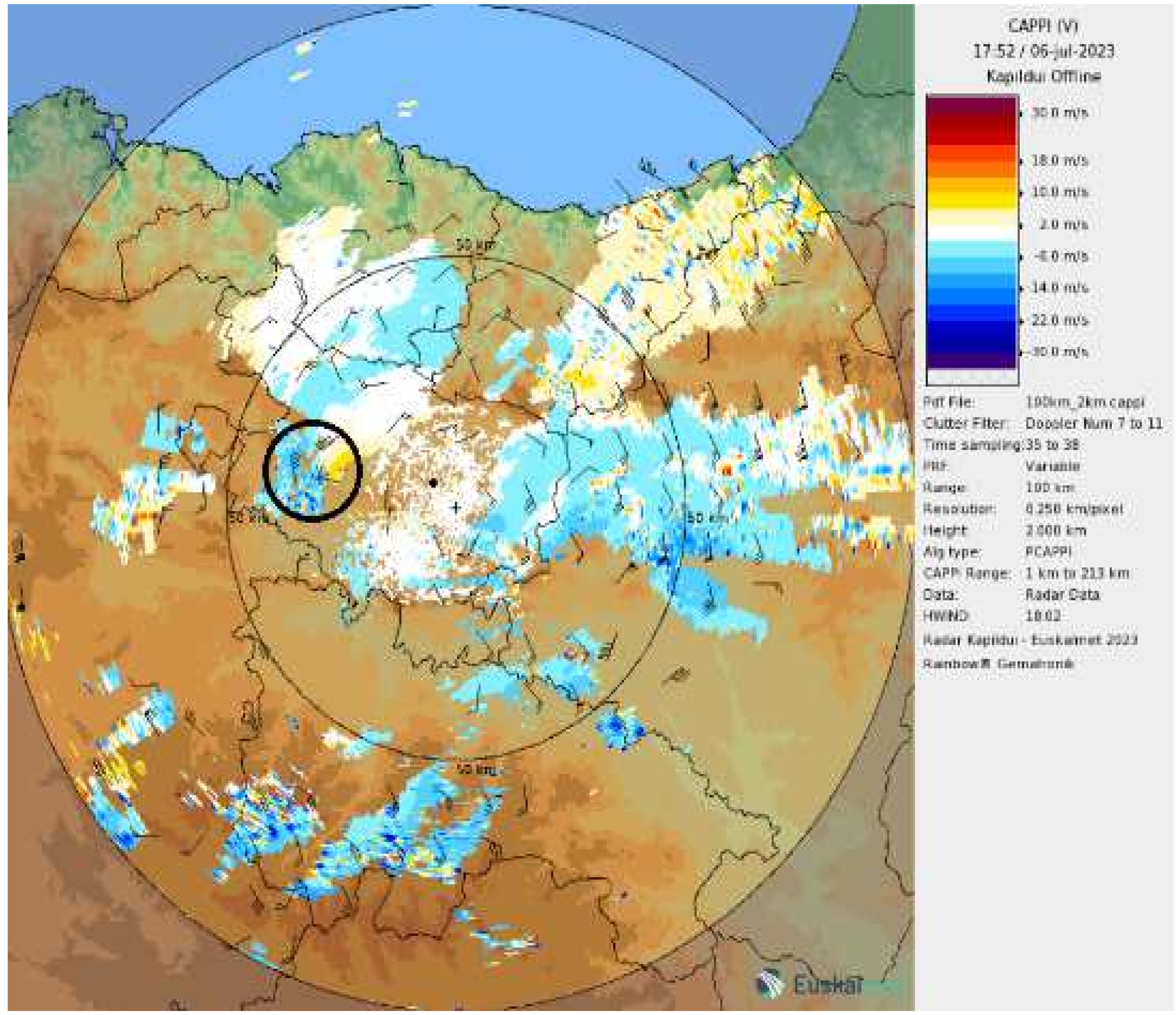


Sounding with the hodograph for Abetxuko (Vitoria-Gasteiz) at 12 UTC (WRF model).





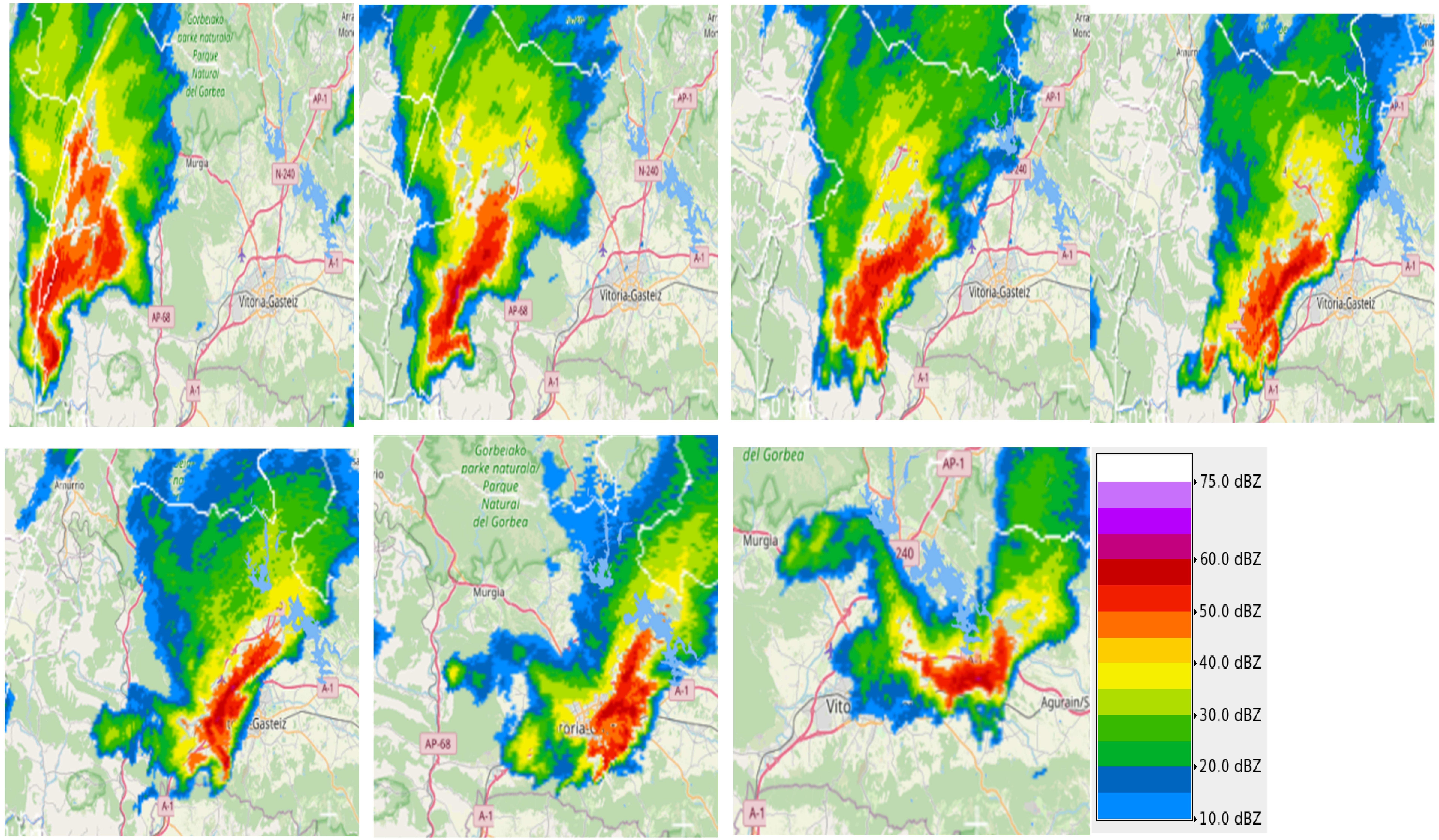
PPI of 0.5º and the radial wind at the CAPPI at 2 km. The echo hook and the characteristic turn in the radial wind are observed, with two relative maxima of opposite winds very close to each other (inbound and outbound velocity maxima).

In this way, this cell, according to the radial wind analysis and the analysis of the reflectivity in the lower layers, presents a supercell structure.

3. Storm environment and observations

This supercell enters Alava at 19:00 hours from the west and moves from west to east without losing activity until it reaches Vitoria-Gasteiz at around 20:15 hours and affects the capital for 10-20 minutes.

The radar shows reflectivities around 55-60 dBz, even occasionally between 60 and 65 dBz. Later, after leaving Vitoria-Gasteiz behind, it loses activity and moves to the northeast, following the average wind at altitude.



CAPPI at 2 km. It can be seen how the supercell affecting Vitoria-Gasteiz moves from west to east. The images show the time interval from 19:30 hours to 20:30 hours every 10 minutes (local time).

3. Storm environment and observations

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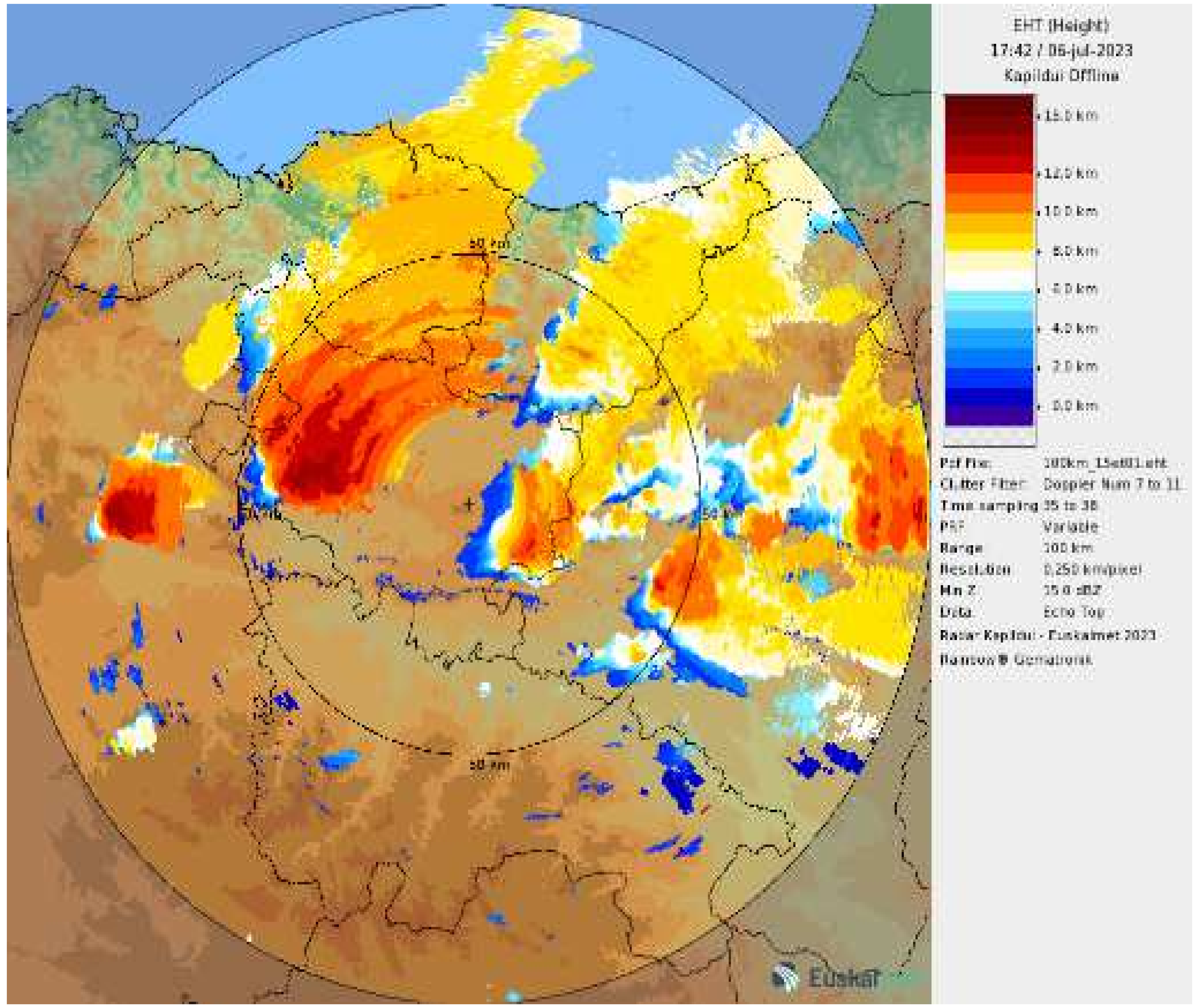
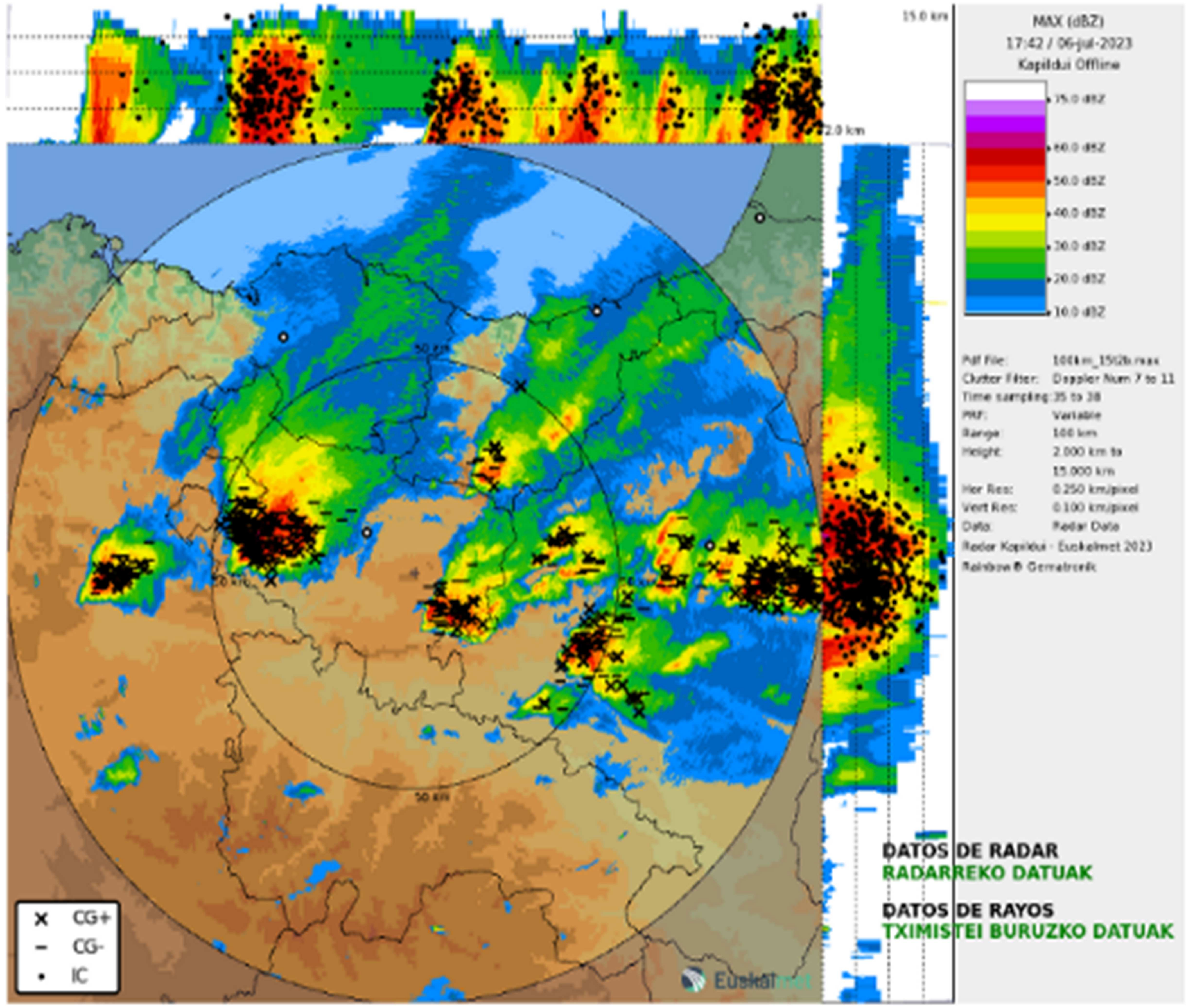
The supercell has a great vertical development, reaching the top of the cloud up to 14-15 km and with a great amount of lightning.





Echotop of 15 dBz and Max product 2-15 km with a great amount of lightning. The supercell can be seen in the west of Alava at 19:40 hours.

3. Storm environment and observations

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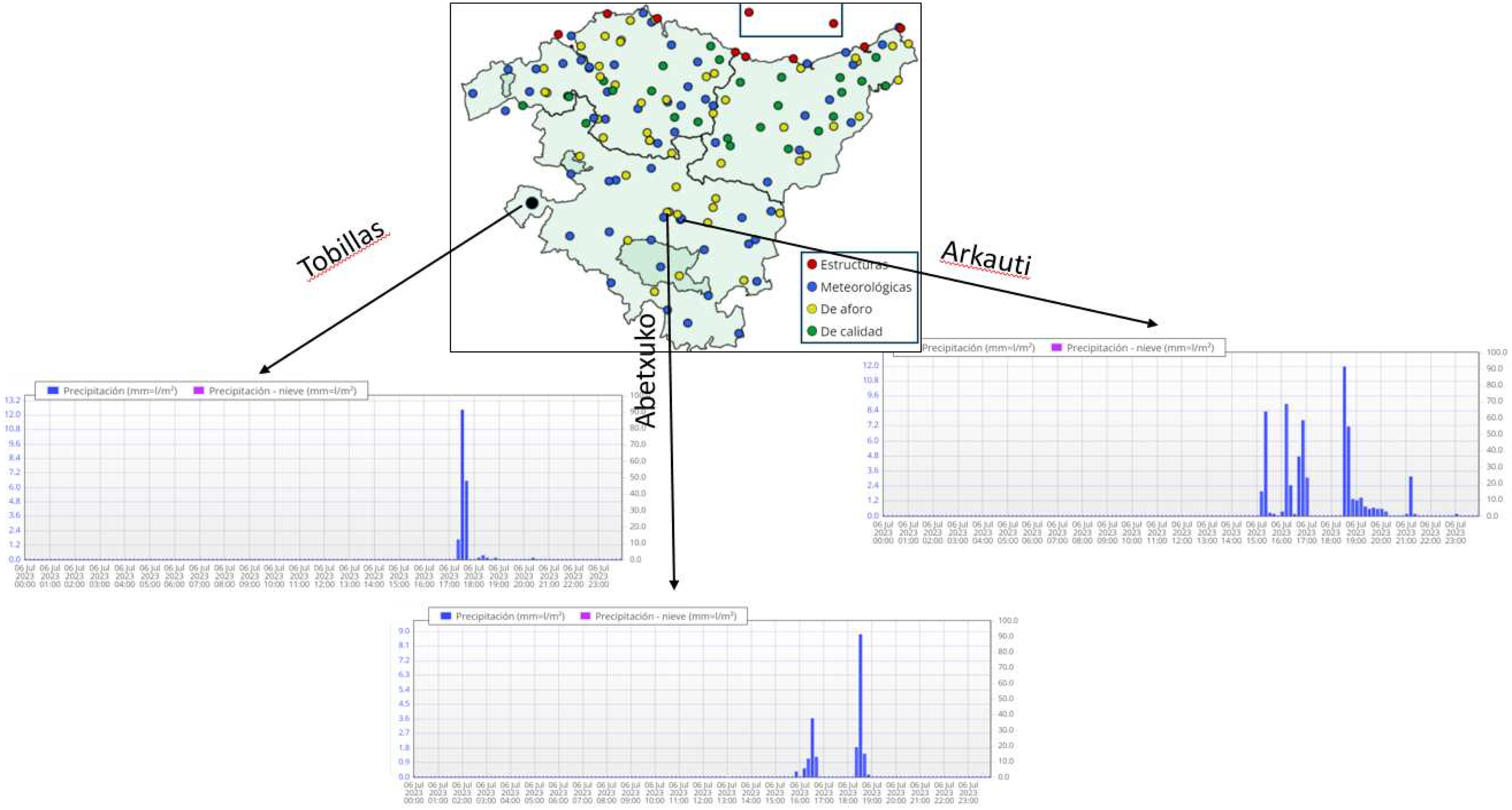
This supercell gives rise to heavy showers with hail in Vitoria-Gasteiz, being in some areas of large size (up to 4-5 cm diameter). The intensity of precipitation in the capital differs substantially from one station to another: in Abetxuko 12.1 mm/h were recorded, with a 10-minute data of 8.8 mm, while in Arkauti 26 mm/h were recorded, with a 10-minute data of 11.9 mm. All the precipitation was recorded in less than 20 minutes.

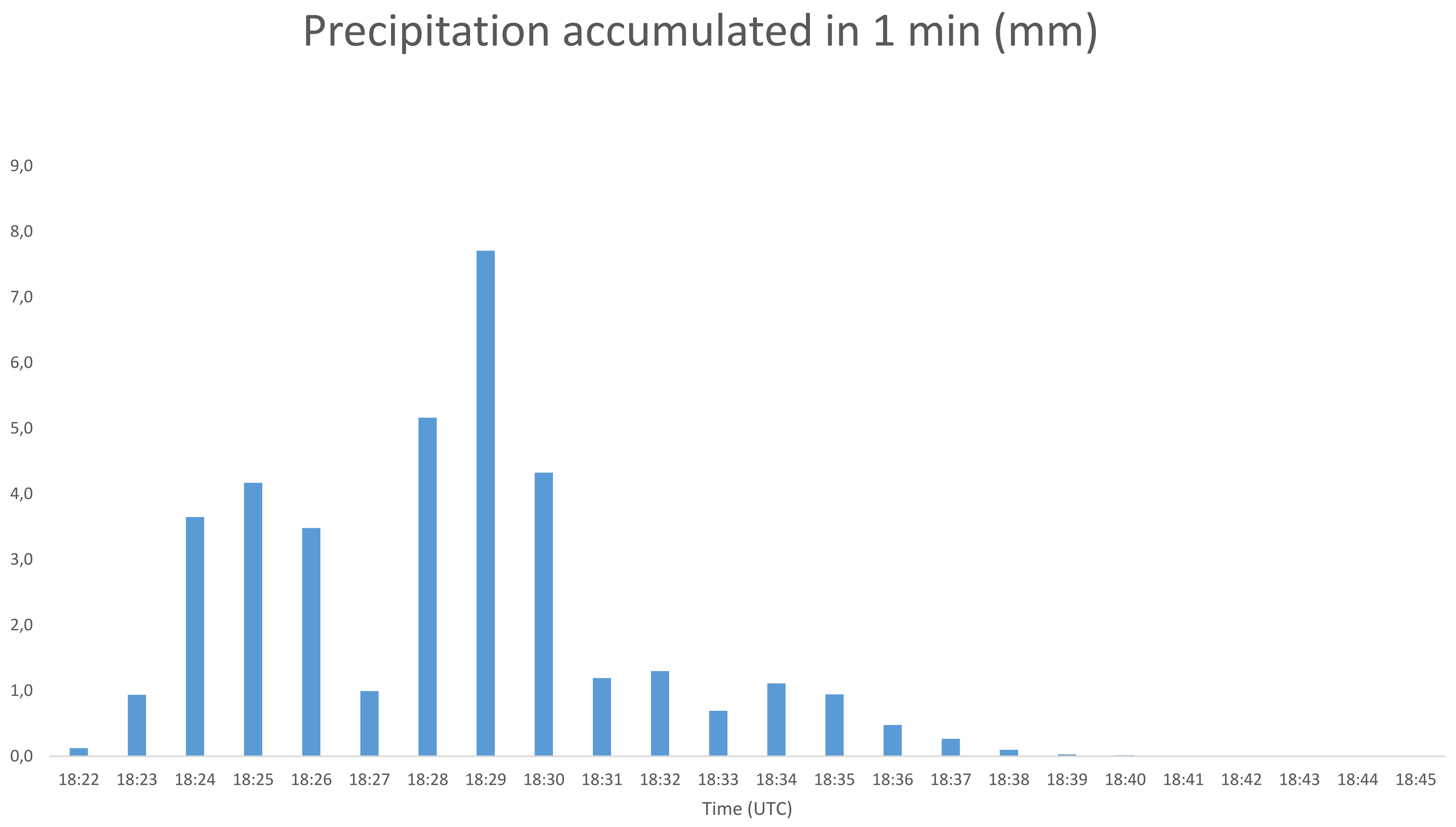


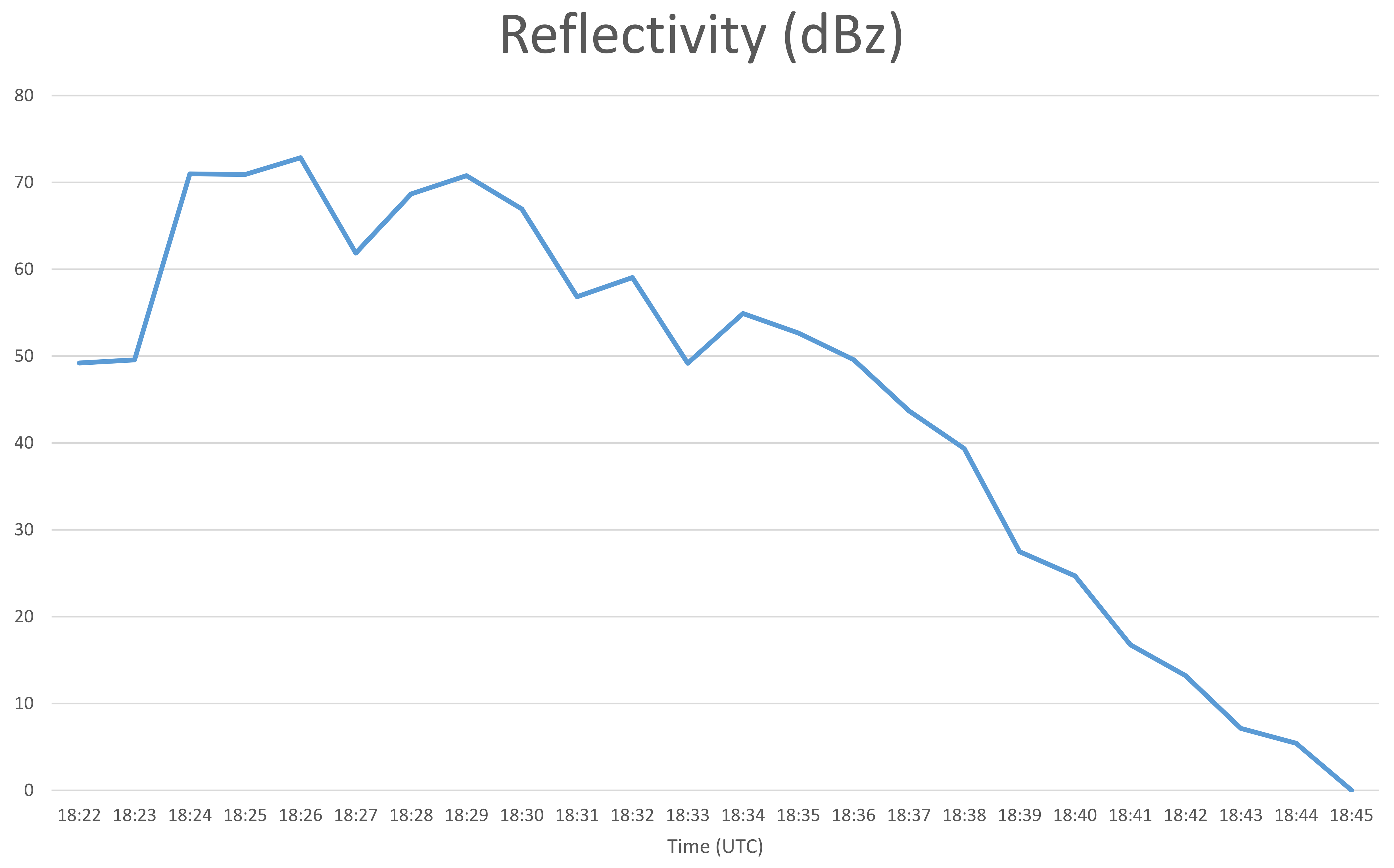
Evolution of precipitation at three stations through which the supercell passes (Tobillas in the west of Alava and two stations in Vitoria-Gasteiz, Abetxuko and Arkauti).

3. Storm environment and observations

If we analyse the data from the disdrometer located near the Arkauti station, we can observe an hourly accumulated rainfall of 36.6 mm, recorded between 20:20 hours and 20:45 hours. Within the 10 minutes between 20:22 and 20:32 hours the accumulated rainfall is 32.9 mm, i.e. most of all the precipitation occurs in just 10 minutes. 7.7 mm were recorded in just 1 minute.

The difference between what was acumulated at the Arkauti station and the disdrometer is probably due to the fact that most of the precipitation is in form of hail. The estimated reflectivity through the disdrometer in the 10 minutes of maximum intensity reaches up to 70 dBz.





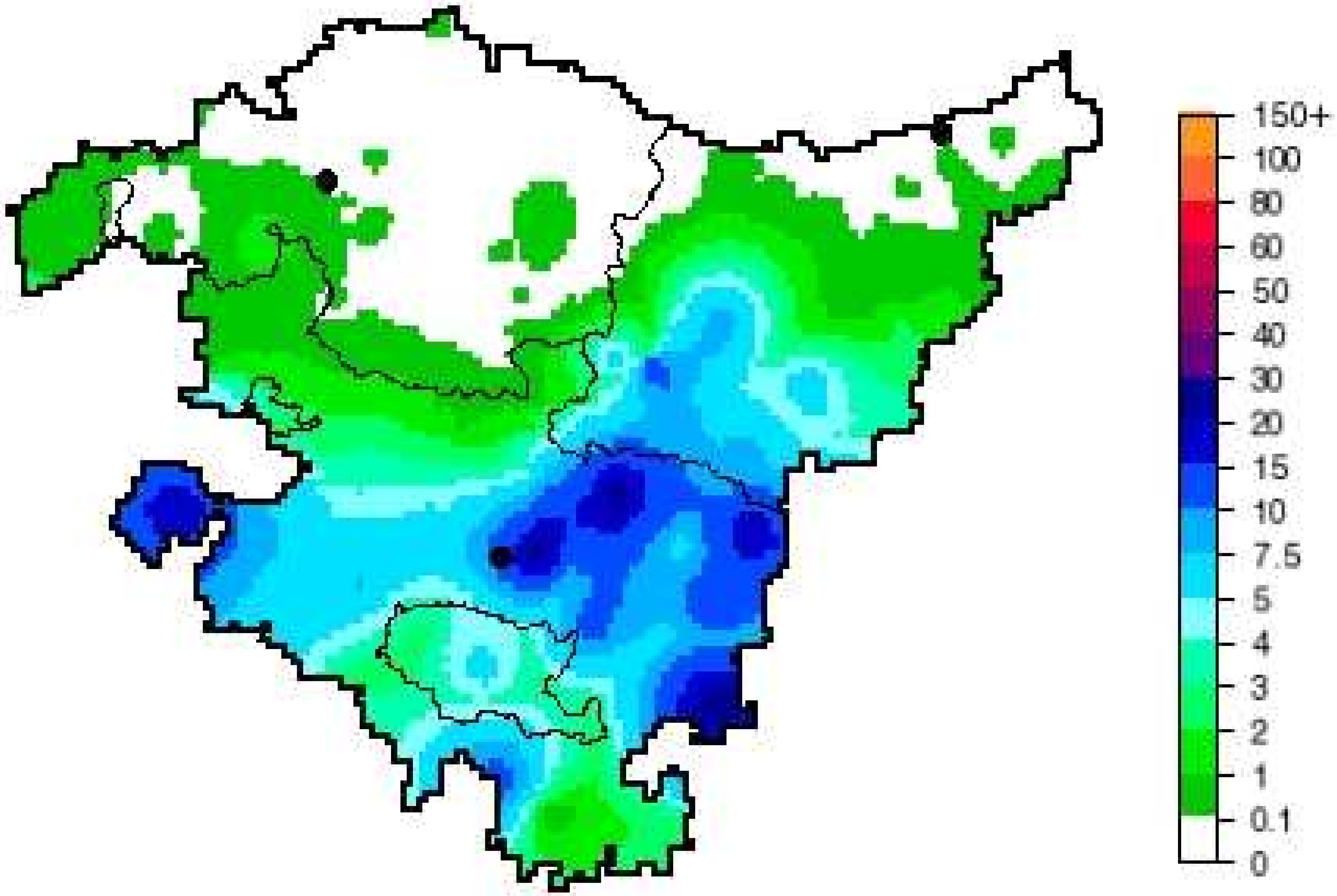
Accumulated 1-minute precipitation and reflectivity in the Arkauti disdrometer.

3. Storm environment and observations

The rainfall intensity recorded at other statio due to other convective cells was also considerably large. Even at the Arkauti stati a previous convective cell also left heavy showers before the arrival of the supercell.

Another storm left heavy showers in the mountains of Alava. The Etura and Ozaeta stations, in the *Llanada Alavesa*, beat the record for hourly and ten-minute rainfall in their July series.

Some of the records: Kanpezu 27.4 mm/h, Arkauti 26.7 mm/h, Ozaeta 26.6 mm/h, Etur 20.9 mm/h, Tobillas 20.6 mm/h.



Maximum precipitation in 1 hour on July 6.

3. Storm environment and observations

The supercell produced numerous incidents and considerable damage in Vitoria-Gasteiz. 11 people were injured with head breaches due to hail reaching a 4-5 cm diameter.

Besides, thousands of cars were damaged, streets and roads collapsed, there was flooding of commercial premises and garages etc. There was also damage to crops, mainly cereals, due to other convective cells.

4. Conclusions

- This hailstorm affecting Vitoria-Gasteiz is the worst since the event of 1 July 2009. On that occasion, the hail even reached larger diameters than this event, but the amount of hail was smaller.
- The supercell that generates this hailstorm in Vitoria is generated in an unstable synoptic environment after a storm splitting, activating the cell that moves to the right of the movement and its trajectory is to the right, dissociating itself from the movement of other cells that follow the average movement, all this according to the hodograph.
- The impact of active storms or, as in this case, of a supercell in an urban environment generates many problems. In fact, Vitoria-Gasteiz, the capital of the Basque Country, is usually affected by a relatively high number of storms of greater or lesser impact.
- From a forecasting point of view, these are complex and particularly delicate situations. In these cases, it is an essential task to perform nowcasting through radar information, detecting the characteristic signs of a supercell and its possible trajectory.

5. Acknowledgments

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✓ Our thanks to Basque Government for maintain and supports research and operational services in the hydro-ocean-meteo-climatic field essential for the Basque community, and particularly to the Department of Security and the Directorate of Emergencies and Meteorology (DAEM) for Euskalmet support.

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Thank you for your attention.